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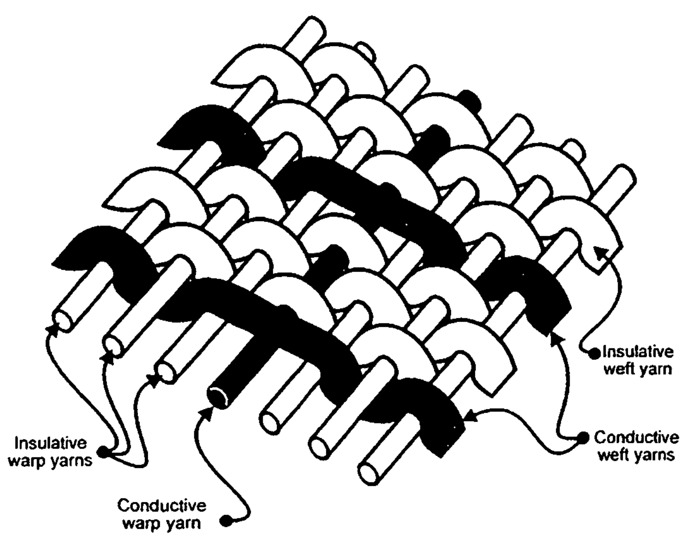
(54) Title: CONDUCTIVE PRESSURE SENSITIVE TEXTILE



Woven piece of fabric, showing conductive and insulative yarns, with weft floats at crossover points between conductors

(57) **Abstract:** A fabric including within its construction a first elongated electrical conductor crossed by a second elongated electrical conductor, the conductors being normally biased apart at a crossover point of said fibres with an air gap between them, whereby application of pressure in a direction substantially normal to a plane of the fabric causes the conductors to make contact. The fabric may be woven, knitted, non-woven or plaited. The fabric can be used as a pressure sensor, switch or other sensor.

WO 01/75778 A1

CONDUCTIVE PRESSURE SENSITIVE TEXTILE

The present invention relates to methods of constructing one or more pressure activated electrical switches or sensors in fabric, in the preferred embodiment as integral elements of a single fabric sheet.

Electrically conductive fabric sheets are known in the art and are described, for example in the applicant's earlier British patent application 2,339,495. The known conductive fabric sheets typically comprise two conductive layers separated by an insulating layer which can be bridged upon application of pressure on the conductive layers. Although such fabric assemblies can function well, there are inevitable drawbacks with having to have three or more fabric layers, including additional cost, fabric thickness, need to maintain alignment between the various layers, movement of the layers during use and so on.

The present invention seeks to provide an improved conductive textile.

According to an aspect of the present invention, there is provided a fabric as specified in claim 1.

The preferred embodiment provides a woven, knitted, non-woven or plaited fabric including in its woven, knitted, non-woven or plaited construction a first elongated electrical conductor crossed by a second elongated electrical conductor, the conductors being normally biased apart at the crossover point with an air gap between them whereby the application of pressure normal to the plane of the fabric causes the conductors to make contact.

Preferably, the fabric includes a plurality of spaced first conductors and/or a plurality of spaced second conductors thereby forming a plurality of said crossover points. The conductors may comprise electrically conductive filaments or fibres.

Advantageously, the fabric is a woven fabric; the warp of which may include at least one said first electrical conductor and the weft may include at least one said second electrical conductor.

The fabric may include a plurality of insulating fibres within one of the weft and warp fibres, which insulating fibres provide a bridge for a conductive fibre in the other of the weft and warp fibres, such that said conductive fibre floats over one or more conductive fibres in the one of the weft and warp fibres.

In another embodiment, one or more insulating fibres is provided around at least one of the conductive fibres, for example helically disposed therearound. Alternatively, one or more conductive fibres could be provided around at least one insulating fibre, with the insulating fibre including portions, for example projections, extending beyond the perimeter of the conductive fibre or fibres. The insulating fibre can thus provide the spacing means for spacing the conductor from other conductors within the fabric layer.

It will be apparent that the invention can provide a conductive textile for a pressure sensor or switch or other conductive device within a single layer of fabric. This can obviate the problems discussed above.

In addition, it is possible to reduce the edge effect (non-linearity of resistance relative to position) which is intrinsic to three-layer structures and which must be corrected for to provide accurate measurements. Moreover, it is possible to have significantly higher resolution, possibly ten times or more, relative to the three layer device; the resolution being dependent upon weaving techniques and fibre dimensions.

With the preferred embodiments, it is possible to provide for contact of the conductive fibres upon the application of a specific pressure or pressures to the fabric and this can be determined by the size of the air gap, the tension of the weave, the deformability of the conductors and the compressibility of the insulators. Moreover, it is possible to provide a range of pressure sensitivities within a single fabric structure. For example, with the embodiment of floating conductor (described with reference to Figure 3 below) different pressure sensitivities can be provided with a plurality of bridges having a different number of conductors below the bridges and/or different insulating fibres, such as different thicknesses or compressibilities. Similar effects can be envisaged with respect to the other embodiments of fibre disclosed herein.

Figure 5 shows various views of an embodiment of yarn;

Figure 6 shows various views of another embodiment of yarn;

Figures 7a to 7c show various embodiments of conductive and insulating yarns;

Figure 8 shows another embodiment of composite yarn;

Figure 9 shows variations of the embodiment of yarn with floating conductors;

Figure 10 is a schematic diagram of an embodiment of woven bus bars;

Figure 11 shows an example of technical specification of weave structure; and

Figure 12 shows an example of individually addressable multiplexed switches within a woven fabric construction.

Referring to the Figures, in the embodiment of Figure 1, the piece of fabric preferably comprises at least two sets of elongate electrical conductors. Typically, the conductors in each set are arranged in parallel relative to one another and one set of conductors is arranged perpendicular relative to the other set to form an arbitrarily spaced grid, as shown in Figure 1. The elongated electrical conductors are typically mono-filament or multi-filament conductive fibres, while the remainder of the piece of fabric is composed of insulating fibres.

Where any two conductors cross over one another, the construction of the fabric and/or the conductive fibres maintains their physical separation, as shown in the cross-sectional view of two conductors in Figure 2(a). When pressure is applied normal to the plane of the fabric, the conductive fibres are caused to deflect and make electrical contact, as in Figure 2(b). Thus, each crossover point constitutes a momentary contact electrical switch, which will maintain contact while the applied pressure exceeds a threshold. The threshold pressure can be predetermined and controlled at manufacture.

share little or no physical contact area, as shown in the cross-sectional view, longitudinal to the weft, of Figure 4(a).

If the conductive warp yarn is of smaller diameter than the surrounding insulating warp yarns, their physical separation can be effected, as shown in Figure 4(b). When pressure is applied normal to the plane of the fabric, the yarns and surrounding fabric deflect, and the two conductors make electrical contact, as in Figure 4(c). Increasing applied pressure increases the area of contact, as in Figure 2(c). The yarns must exhibit sufficient elasticity to recover from the deflection upon removal of the applied pressure, and thus return to their separated positions, breaking the electrical contact.

Separation technique - Conductive cored yarn encircled with displaceable insulator

Another separation technique involves using a specific composite construction for the conductive yarns. In this composite yarn, a conductive mono-filament or multi-filament core yarn is twisted, braided, spun, plaited, co-moulded, coated, sleeved or otherwise partially encircled by insulating material, as shown in Figure 5(a).

When a crossover point between two conductive yarns, at least one of which is of this nature, is not subject to pressure, the insulating material is interposed between the conductors, as in Figure 5(b), ensuring physical separation. However, when subjected to pressure normal to the plane of the fabric, the encircling insulating material can twist, compress, move aside or otherwise deflect to allow electrical contact between the core conductor yarns, as Figure 5(c) shows. Upon removal of the applied pressure, the insulating material springs back into position and/or shape between the conductors to break (open) the electrical contact.

The geometry of the composite yarn and the compressibility, stiffness and surface textures of its constituent yarns contribute to determining the pressure threshold of a crossover point and can readily be determined by experiment. Composite yarns of this type may be used to construct plain weave crossover points, without the float structures described above.

Separation technique – Conductive Cored Yarn Encircled with Displaceable Insulator

Referring to Figures 7(a) to 7(c), there are shown various embodiments of yarn with both insulator and conductor. In Figure 7(a) there is a core yarn substantially circular in cross-section which can be insulating or conductive as desired. Spun, braided or twisted around the core there are larger diameter insulating yarns and smaller diameter conductive yarns. As can be seen in the Figures, when no pressure is applied to the yarn, the conductive fibres remain spaced from the other conductor(s). However, upon application of a compressing force above the threshold, the insulating yarns are compressed and/or moved to allow contact of the conductive yarns on the conductive base (which may be another composite yarn of this type).

In Figure 7(b) there is simply a conductive core having coated thereon or extruded therewith one or more insulating ribs, preferably in a helical arrangement. As can be seen, when no pressure is applied, the conductive core remains spaced from any conductive base upon which the composite is placed (the base may be the another composite structure such as this). However, upon application of a compressive force, there is compression of the insulating rib(s) to allow electrical contact.

In Figure 7(c) a deformable conductive core has formed therewith an insulating sleeve from which sections are then removed to leave grooves with conductive troughs. Compression of the structure will cause deformation of the grooves such that a conductive substrate, which may for example be a plate or fibre-like conductor, will make electrical contact with the conductive core. It is not necessary for any part of the conductive core to be removed to create the groove, merely to enough insulator to be removed to allow access to the core.

Separation technique – Self-Separating Sensory Composite Yarn

In Figure 8 there is shown an embodiment of composite yarn having a core around which there is braided a conductive/insulating yarn with floating conductors, which enables the detection of pressure applied at a point along the length of the structure.

d) Number of adjacent conductive yarns

If multiple adjacent conductive yarns are used instead of a single warp or weft conductive yarn, as in Figure 9(a), the actuation pressure is reduced. Wider conductors with a greater number of adjacent yarns, as shown in Figure 9(b), both offer a larger contact area at a crossover point and require less angular deflection of the yarns, and thus less pressure, to make contact.

e) Number of yarns floated

If a conductive weft yarn is floated over a minimum number of warp yarns to ensure separation at a crossover point, as shown in Figure 9(a), the actuation pressure is correspondingly lesser than if the conductive weft is floated over a larger number of adjacent warp yarns, as shown in Figure 9(c).

Implications to note on actuation pressures

Controlling the aforementioned manufacturing parameters allows crossover points with predetermined actuation pressures to be woven into a piece of fabric. The threshold pressures for both electrical contact to be made and maximal contact to be achieved can be determined independently. Crossover points with different pressure thresholds may be incorporated into a single piece of fabric. This enables the construction of, for instance, a group of neighbouring crossover points that make contact consecutively with increasing pressure and together constitute a quantised pressure sensor.

Another implication of controlling the parameters at a crossover point is that the two conductive yarns may be woven to be in permanent electrical contact, regardless of applied pressure. Principally, this may be achieved through the use of a plain weave structure at the crossover point, where the conductive weft is not floated over any additional warps, but instead shares a large, permanent contact area with the conductive warp yarn. This allows, for instance, the woven construction of bus-bars, discussed herein.

For example, first assume that the conductive yarns of the matrix exhibit a linear resistivity, and that connections are made to three perfectly conductive bus-bars as shown in Figure 10. If the switch at crossover point D is closed, the resistance RAB measured from bus-bar A to bus-bar B is given by:

$$RAB = K (X + Y)$$

where K is a constant determined by the absolute lengths, cross-sectional areas and resistivities of the conductive yarns, and distances X and Y are the orthogonal vector components of point D, where

$$0 <= (X,Y) <= 1.$$

Similarly, the resistance measured from bus-bar B to bus-bar C is given by:

$$RBC = K (Y + 1 - X).$$

Substituting gives:

$$X = [((RAB) / K) - ((RBC) / K) + 1] / 2$$

and:

$$Y = [((RAB) / K) + ((RBC) / K) - 1] / 2.$$

A typical example

This section details an example of weaving instructions for constructing a typical piece of fabric. A piece of fabric of arbitrary size may be reproduced from these specifications, although the repeat for a 250 mm width has been included. The crossover points are evenly spaced in a grid some 8.5 mm apart. Using the specified yarns and weave structures, the pressure threshold of the crossover points is roughly 80 kiloPascals, equivalent to 4

CLAIMS

1. A fabric including within its construction a first elongated electrical conductor crossed by a second elongated electrical conductor, said conductors being normally biased apart at a crossover point of said fibres with an air gap between them, whereby application of pressure in a direction substantially normal to a plane of the fabric causes the conductors to make contact.

2. A fabric according to claim 1, including a plurality of spaced first conductors and/or a plurality of spaced second conductors, forming a plurality of said crossover points.

3. A fabric according to claim 1 or 2, wherein the conductors comprise electrically conductive filaments or fibres.

4. A fabric according to any one of claims 1 to 3, which is woven, knitted, non-woven or plaited.

5. A fabric according to claim 4, including warp and weft filaments, wherein the warp filaments include said first electrical conductor or conductors and the weft filaments include said second electrical conductor or conductors.

6. A fabric according to any preceding claim, including insulating fibres or filaments which bias the first and second electrical conductors apart at the crossover point.

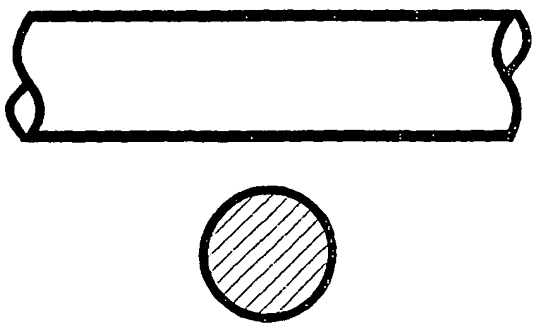
7. A fabric according to claim 6, wherein said biasing apart is effected by locating an electrical conductor of relatively smaller cross-section between insulating filaments or fibres of relatively larger cross-section.

8. A fabric according to claim 6, wherein the weave includes warp and/or weft floats over more than one yarn to effect the biasing apart of first and second electrical conductors at the crossover point.

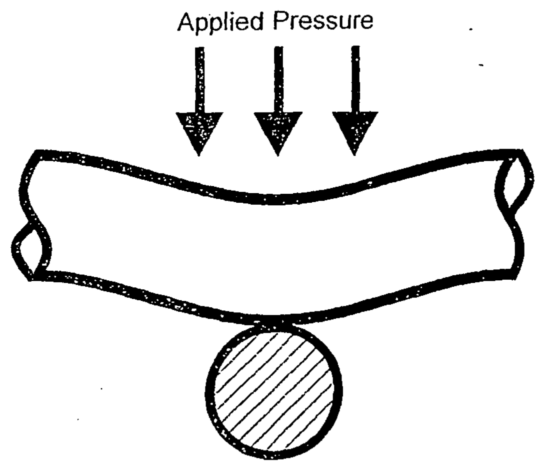
16. A fabric according to claim 14, wherein set of spaced electrical conductors comprises electrically conductive filaments or fibres in the warp or weft of a woven construction and said electrical connection is effected after the weaving process.

17. A fibre including an insulating yarn and a conductive yarn, the insulating yarn including portions extending beyond the conductive yarn.

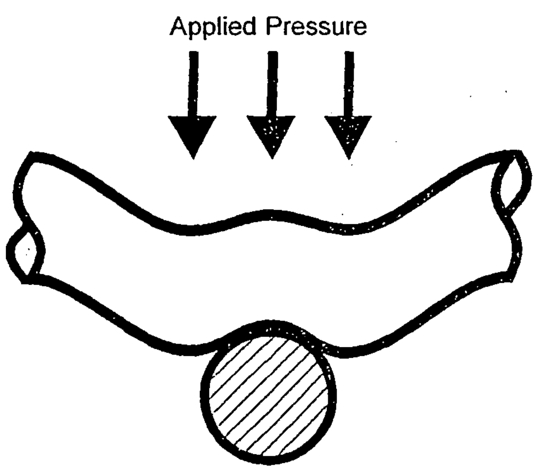
18. A fibre according to claim 17, wherein there are provided two or more conductive yarns helically wound around the insulating yarn.



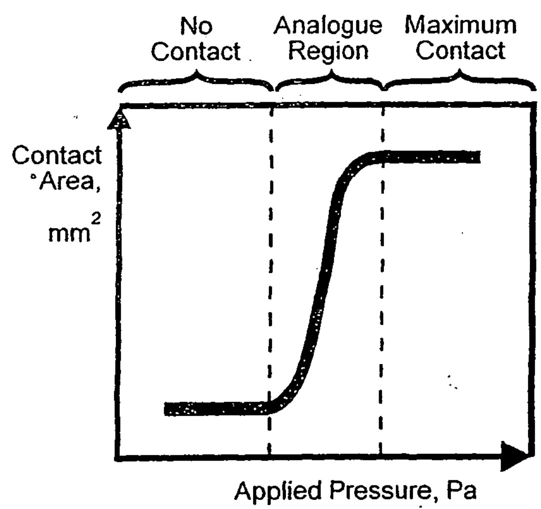
a) No contact area
between conductors



b) Little contact area
between conductors

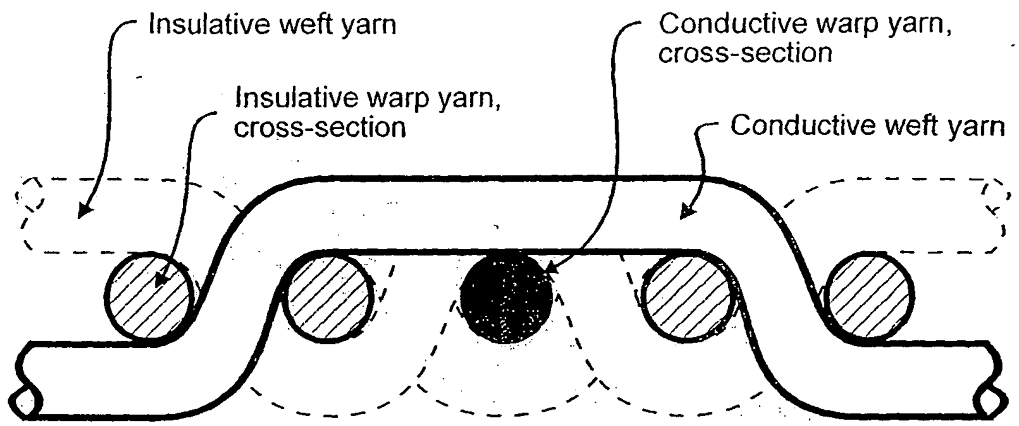


c) Maximum contact area
between conductors

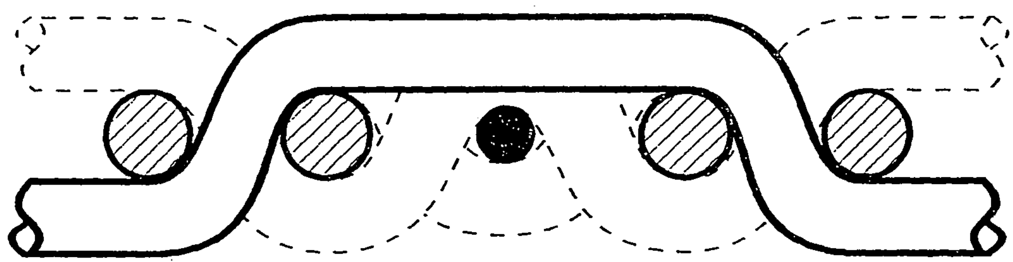


d) Graph of applied pressure on a
crossover vesus area of contact
between the conductors,
showing analogue switching region

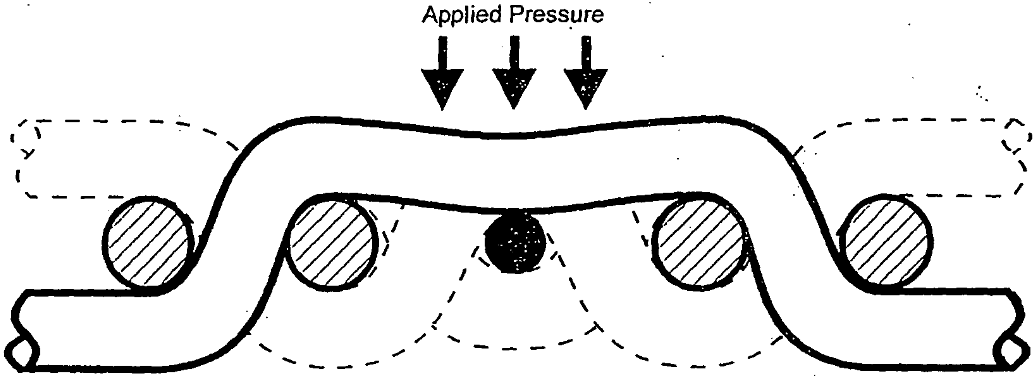
Figure 2. Effects of applied pressure on a crossover between two conductors,
cross sectional views and plotted relationship



a) Conductive weft floated over conductive warp results in minimal contact area

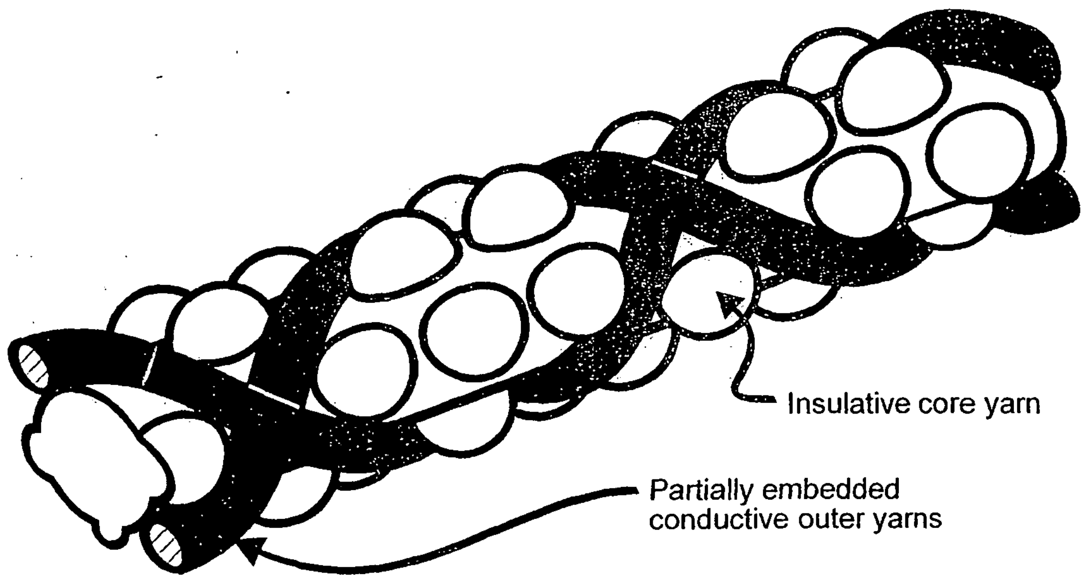


b) As (a) but smaller diameter conductive warp results in physical separation

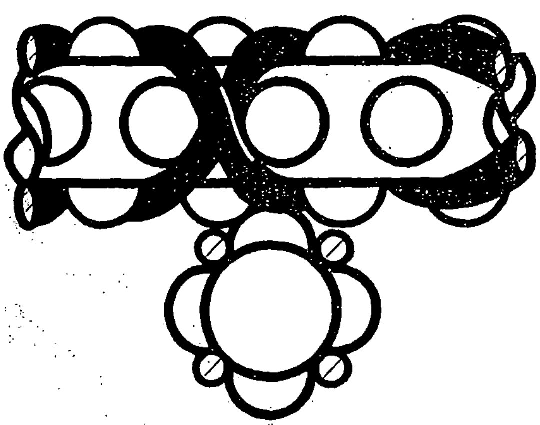


c) Pressure applied to structure (b) effects contact between the conductors

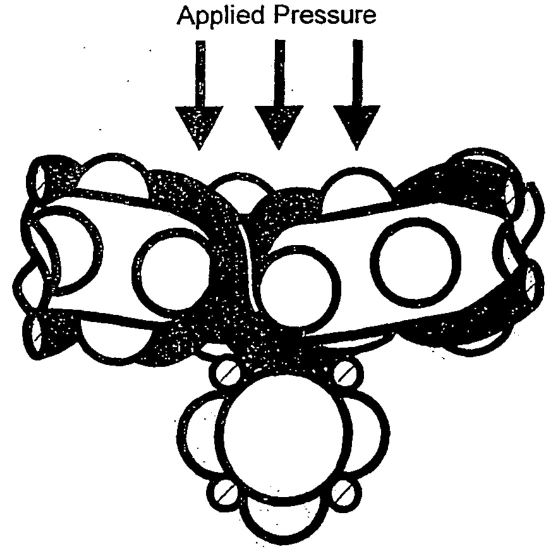
Figure 4. Weaving conductive yarns with weft floats at crossovers to control contact area, cross sectional views



a) Conductive encircling yarn partially embedded into insulative core yarn, perspective view



b) Insulative core stands proud of conductive yarns, holding them apart



c) Applied pressure compresses the insulative yarn surface, allowing conductive yarns to make contact

Figure 6. Insulative cored yarn with embedded conductive yarns as a separation technique

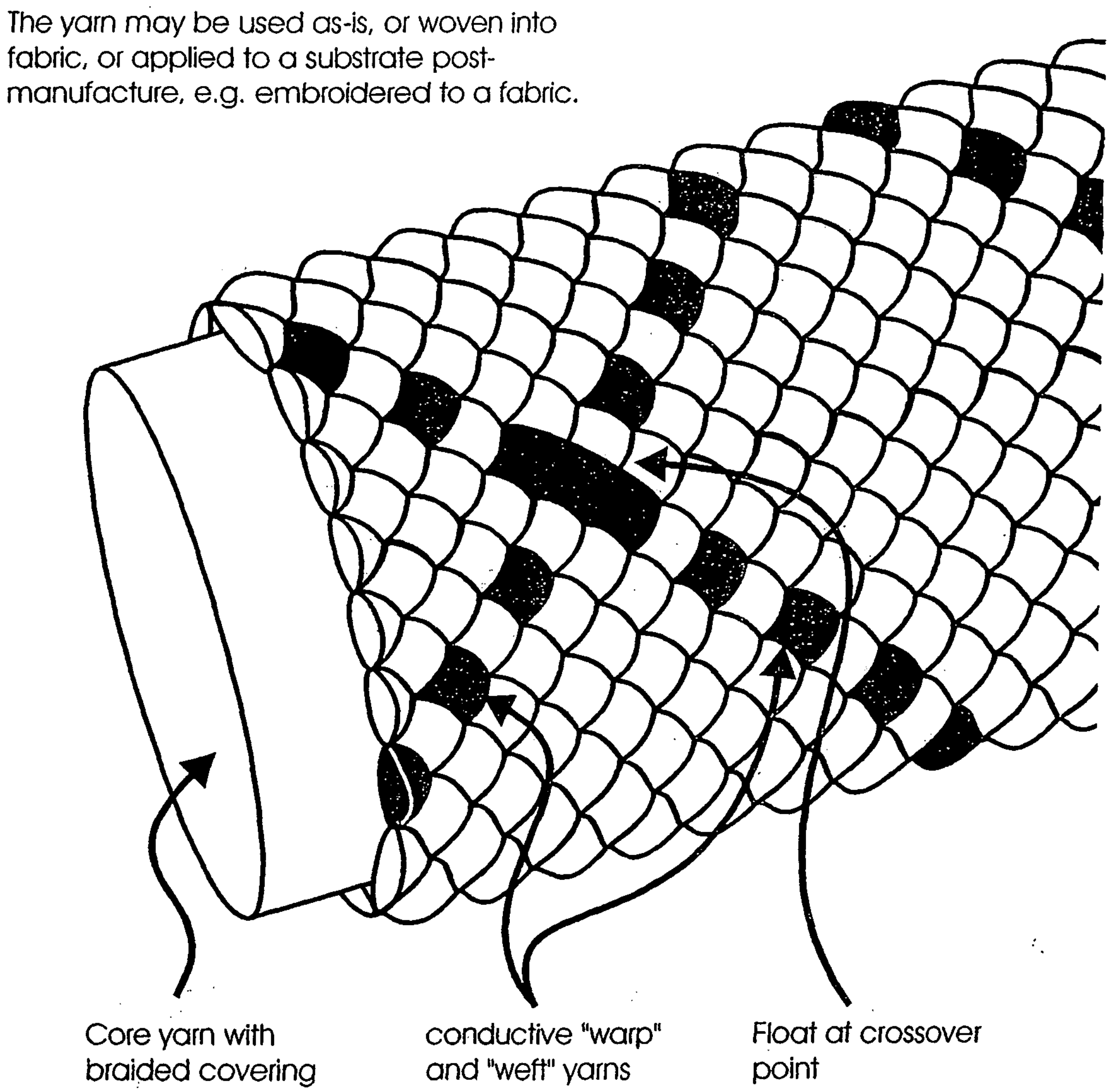


Figure 8. Translation of the described techniques from a weaving to a braiding process. The resulting composite yarn can detect an applied pressure at some point along its length

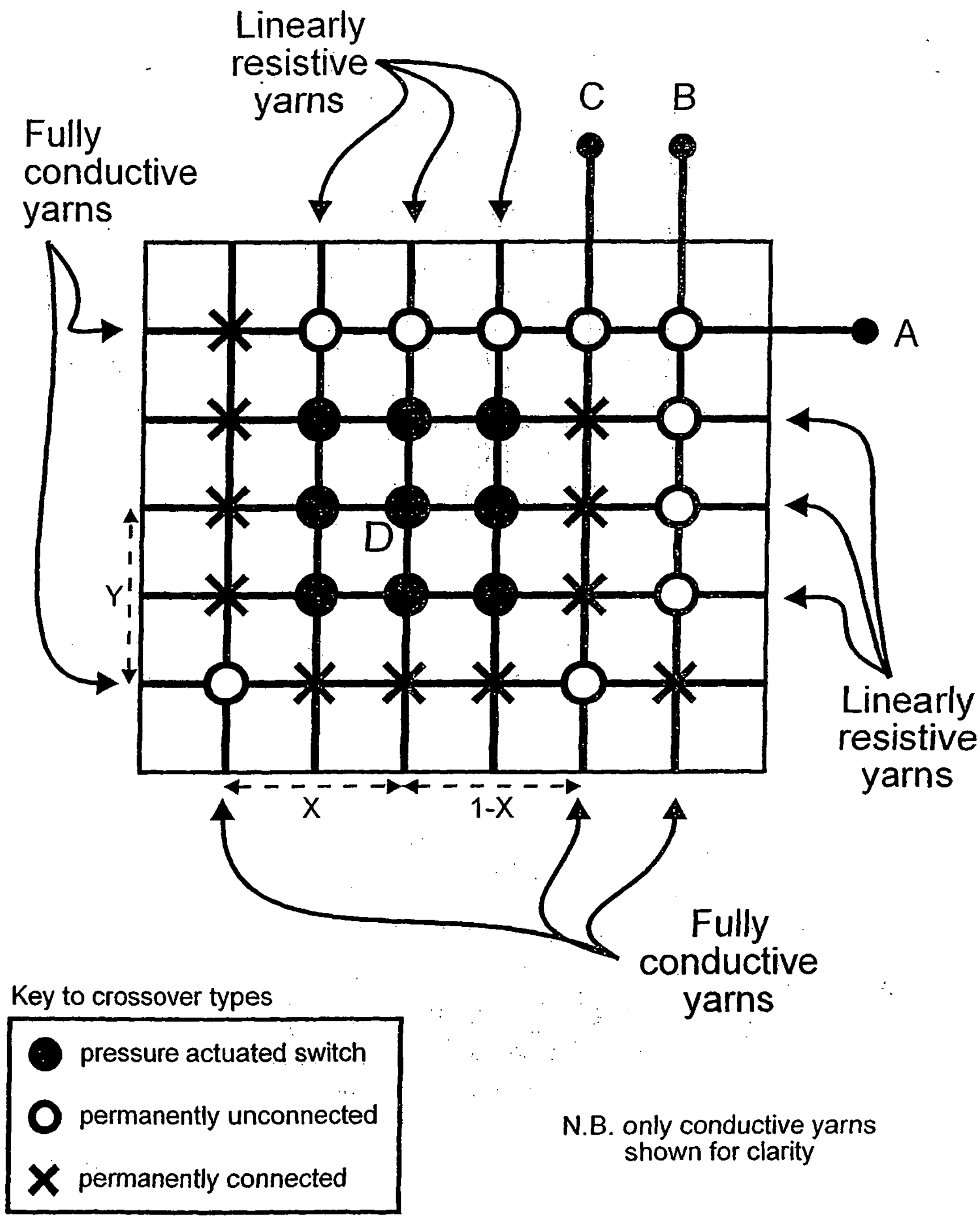
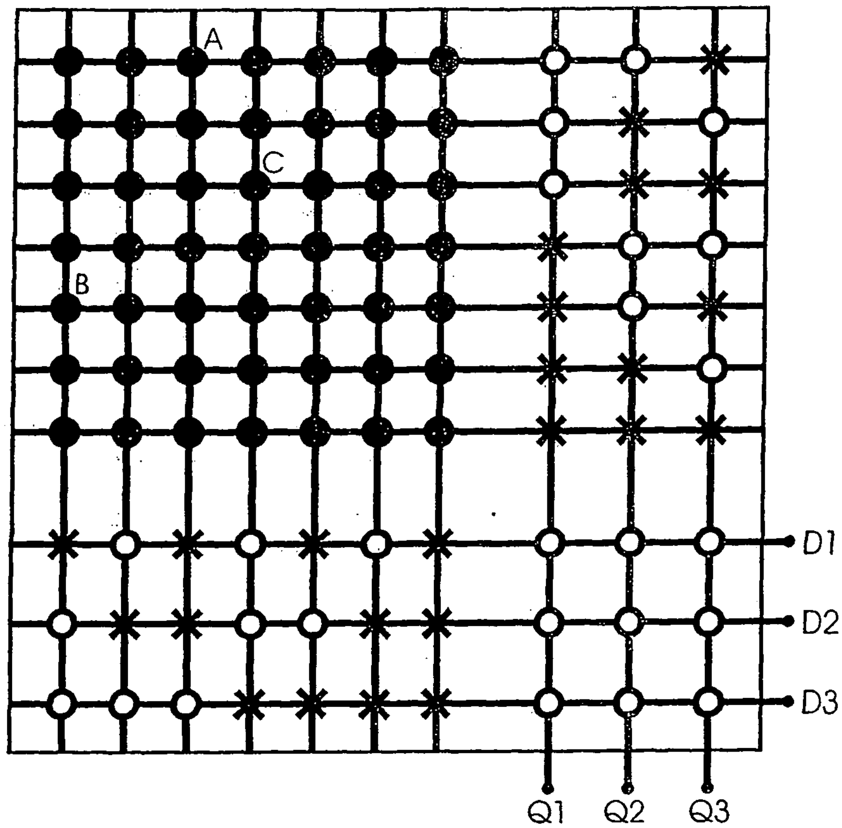


Figure 10. Woven bus-bars: arrangement and weave structure



Examples of matrix interrogations

Switch	D1	D2	D3	Q1	Q2	Q3
PointA	1	0	0	0	0	1
	0	1	0	0	0	1
	0	0	1	0	0	0
PointB	1	0	0	1	0	1
	0	1	0	0	0	0
	0	0	1	0	0	0
PointC	1	0	0	0	0	0
	0	1	0	1	0	0
	0	0	1	0	1	1

N.B. only conductive yarns shown for clarity

Key to crossover types

- ● pressure actuated switch
- ○ permanently unconnected
- ✕ permanently connected

Figure 12. Individually addressable multiplexed switches within a woven fabric construction

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